DESIGN OF A REINFORCED CONCRETE FREIGHT AND RECREATION PIER

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ARMOUR INSTITUTE OF TECHNOLOGY

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DESIGN OF A REINFORCED CONCRETE FREIGHT AND RECREATION PIER

A THESIS

PRESENTED BY
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PREFACE

The following thesis is based on the now prevailing thought in the minds of Chicago's Commerical Men, namely that the City's future lies to a great measure in the way of Lake Commerce. Lake Commerce leads to harbor facilities, and in this line Chicago is very weak.

At the present time there is under construction at the lake end of Grand Ave., a freight and recreation pier. This is the genesis of Chicago's greater harbor developement, and is in keeping with the plans of a "City Beautiful". Such a pier will not only afford great advantages to the commerical men, but will afford untold advantages to the general public of the city in the way of recreation. The idea of the greatest good to the greatest number, here holds true.

In keeping with the idea we have chosen for our thesis the design of a similar

structure, to be located at the lake end of Twenty Second Street. In our work we do not touch upon the architectural end of the work, but solely upon the engineering features presented in designing the freight and recreation sheds of the pier.

The thesis may be divided into three parts, namely the calculations and data necessary for the design, the plans and details following these calculations, the specifications covering the erection and completion of this part of the pier.

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DESIGN OF A REINFORCED CONCRETE PIER

INTRODUCTION

There is at the present time a pressing need of harbor facilities for the City of Chicago. It is a notorious fact that the lake Commerce of Chicago, once the pride and boast of this city has been steadily decreasing for the past fifteen years. Careful and comprehensive consideration of the cause of this is now under way. This city now ranks fourth in lake commerce, where once it stood in first place. Without counting the ore shipments from the iron region of the Northwest, the City of Duluth, which is but a pigmy compared with Chicago and which serves as a distributing center for a much smaller territory, ranks above this city in general lake commerce. The reason is perfectly obvious.

Chicago's hinterland is as rich and promising as that of any harbor in the world. The possibilities of Chicago, located in a remarkably rich agricultural and stockraising

area, adjacent to abundant coal fields and possessed of unsurpassed advantages as a manufacturing and jobbing center, are almost unlimited. Chicago already has commerce that not only warrants, but imperatively demands better harbor facilities.

The one and only reason for Chicago's decline in this respect is the inconvenience and inadequacy of its harbor facilities. The time has come when Chicago must decide whether it will depend for the future, entirely upon the harborage afforded by the Chicago River or whether it should not take steps to utilize at least some portion of its lake front for shipping purposes. Many millions of dollars could be spent in deepening and widening the river, but even then it would be inadequate for the lake commerce that Chicago ought to have. For this reason efforts have been centered upon the lake front, where many unforseen advantages lie hidden. The develope-

ment of the Chicago harbor by occupation of its lake front by piers and docks behind an exterior breakwater has been consistently advocated by the Federal Engineering department since 1867. Since the organization of the Gulf to Great Lakes Deep Waterways Commission this fact has been kept before the public. Now we find all schemes for greater Chicago centering about its harbor facilities. The now prominent scheme of the City Beautiful is endowed with a wonderful harbor scheme. Following this scheme a pier is now being constructed at the extreme north end of the proposed harbor, namely at the lake end of Grand Avenue. This pier is a combination freight and recreation pier and is one of the best of its type in the world.

Following out the lines set forth in the same scheme we are designing for our thesis a pier to occupy the southern boundary of this great harbor, namely at the lake end of Twenty Second Street. This pier is also to be a

freight and recreation pier.

The first requisite of a harbor is that it shall give anchorage and refuge for vessels in time of storm. It should be broad and deep enough to accommodate the largest vessels. These should be able to enter and move about under their own steam. It is desirable, though not essential, that vessels should be able to move from their anchorage to loading and unloading docks under their own steam, and to save the necessity of towing. This latter obstacle may be overcome by making the pier large enough to handle both incoming and outgoing freight.

These requirements apply to all harbors, but at large cities provision must be made for the delivery of passengers and freight simultaneously. This is the condition which confronts the engineer in the improvement of the Chicago harbor. Such a harbor requires docks, warehouses and unloading facilities near, or

convenient to, the heart of the city, and may be termed the "Commercial Harbor". An entirely different class of requirements arises in connection with the handling of commodities which are in transit through the city or which are required for manufacturing. A harbor supplied with facilities for handling such traffic may be called the "Industrial Harbor".

All traffic through the city, or moving from lake to rail, or rail to lake, cannot be handled at an outside harbor unless special provision is made for it. For this reason railraod facilities are provided upon the pier. This satisfies the essential requirement both for the Commerical and Industrial harbor, namely that provision is made for easy and convenient interchange of boat and rail traffic. Labor saving machinery will be provided for handling the freight. Sightliness is not a requirement for purposes of

navigation, but there is no good reason why structures devoted to shipping uses should not be pleasing to the eye. In some European ports much thought is given to artistic harbor developement with gratifying results. It is however not the intent of this thesis to go so far into the matter as to take up this essential quality. On the other hand we take up merely the engineering end of the main freight and recreation sheds.

This thesis comprises the design of the main substructure and the main superstructure. The design of the approach or of the recreation pavilion at the far end of the pier is not included.

To accommodate both passenger and freight patrons the combination freight and recreation pier is devised. The lower part or ground floor of this pier is made up of the unloading and loading platfoms, the freight sheds, roadway and railway tracks. This entire ground floor is devoted to freight handling. Vehicle traffic will find no obstruction on the ground

floor as the entire center portion will be paved with granite blocks, laid flush with the top of the rails.

The second floor of the freight sheds is made a recreation floor. The three hinged roof arch is so designed and chosen to give ample room, no clumns interrupting the floor area. The walk along the roof edge is for receiving passengers and may be used for a promenade. Street cars are brought to the second floor level and loop the entire structure at this level.

Three-hinged Arch

$K = \text{rise} = 24'-0''$ $\qquad$ $C = \tfrac{1}{2}l = 40'-0''$

ne's Graphics. Pg. 33

$$P_1 = \frac{(c-b)W}{2c}. \qquad \text{For load unity } W=1 \quad \therefore P_1 = \frac{(c-b)}{2c}$$

$$P_2 = \frac{(c+b)W}{2c}. \qquad P_2 = \frac{(c+b)}{2c}$$

$$H = \frac{(c-b)W}{2K}. \qquad H = \frac{(c-b)}{2K}$$

b = distance of load from center.

Load unity at ①

$P_1 = 1 \qquad P_2 = 0 \qquad H = 0$

Load unity at ②

$P_1 = \frac{40+30}{2 \cdot 40} = \frac{7}{8} = .875 \qquad P_2 = \frac{40-30}{80} = \frac{1}{8} = .125$

$H = \frac{40-30}{2 \cdot 24} = \frac{10}{48} = .208.$

Load unity at ③

$P_1 = \frac{40+20}{80} = \frac{3}{4} = .75 \qquad P_2 = \frac{40-20}{80} = \frac{1}{4} = .25$

$H = \frac{20}{48} = .416$

Load unity at ④

$P_1 = \frac{40+10}{80} = \frac{5}{8} = .625 \qquad P_2 = \frac{40-10}{80} = \frac{3}{8} = .375$

$H = \frac{30}{48} = .625.$

Load unity at ⑤

This load produces P_1' at ④ and P_2' at ⑥: it also produces H' at ④ and ⑥. Hinges at ④, ⑤ and ⑥ cause load at ⑤ to be tranferred directly to ④ and ⑥.

Load unity at ⑤ will $\therefore$ cause a load $= P_1'$ or $\tfrac{1}{2}$ at ④; and a load $= P_2' = \tfrac{1}{2}$ at ⑥. It also causes at ④ a horizontal load $= H' = \frac{10}{19\frac{1}{3}} = .517$ and a horizontal load $= .517$ at ⑥.

Loads at ⑥, ⑦, ⑧ and ⑨ produce same effects as loads ①, ②, ③, and ④.

Horizontal Unit force at ①.

Moments about "b" $V_1 \cdot l = -H \cdot 17.$

$$V_1 = -\frac{17\ H}{l} = -\frac{17}{80} = -\ 2125.$$

$$V_2 = +\frac{17H}{l} = +.2125$$

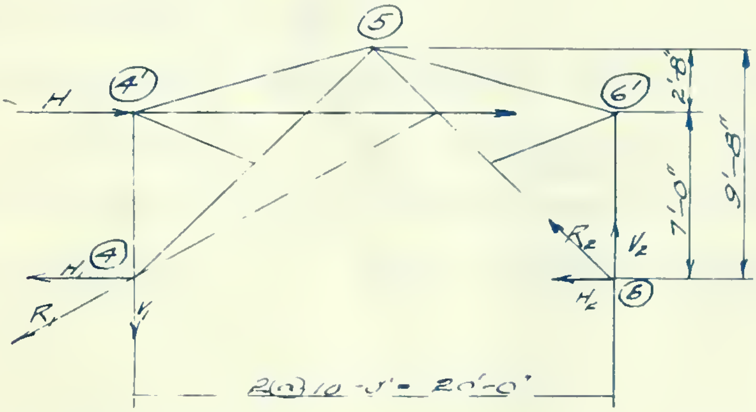
Horizontal Unit force at ④.

Moments about "b" $V_1\, l = -H \cdot 25$

$$V_1 = -\frac{25H}{l} = \frac{-25}{80} = -.3125.$$

$$V_2 = +\frac{25H}{l} = +.3125$$

Horizontal Unit force at ④'.



"H" at ④' is resolved into H_1 and V_1 at ④ ; and into H_2 and V_2 at ⑥.

Moments about ⑥, and then about ④, and we get

$V_1 \cdot 20 + H \cdot 7 = 0$, or $V_1 = -\frac{7H}{20} = \frac{-7}{20} = -.35$ and

$V_2 = +\frac{7H}{20} = +.35$

Take moments about ⑤ – Use section to right of ⑤.

$H_2 \cdot 9\tfrac{2}{3} - V_2 \cdot 10 = 0.$ $\quad H_2 = \frac{V_2 \cdot 10}{9\tfrac{2}{3}} = \frac{.35 \cdot 10}{9\tfrac{2}{3}} = .362.$

Take moments about ⑤ Use section to left of ⑤.

$V_1 \cdot 10 - H \cdot 2\tfrac{2}{3} - H_1 \cdot 9\tfrac{2}{3} = 0$ $\quad H_1 = -\left(\frac{.35 \cdot 10 + 2\tfrac{2}{3}}{9\tfrac{2}{3}}\right) = -\frac{37}{2 \cdot 29} = -.638.$

Reactions act as arrows indicate.

Calculations of H-Components of reactions due to Horizontal forces. Horizontal force at ①

$V_1 = -V_2 = -.2125.$ (Preceding Page)

Take moments about center hinge "C" and consider the portion of the truss to the left of the hinge.

$V_1 \cdot 40 - H \cdot 7 - H_1 \cdot 24 = 0$ $\qquad H_1 = \frac{-.2125 \cdot 40 - 7}{24} = -.646$

Take moments about "C" and consider truss to right of "C".

$-V_2 \cdot 40 + H_2 \cdot 24 = 0$ $\qquad H_2 = \frac{.2125 \cdot 40}{24} = +.354.$

Horizontal Force at ④

Take mom's. about "C" and consider truss to left of "C".

$V_1 \cdot 40 + H \cdot 1 - H_1 \cdot 24 = 0$ $\qquad H_1 = -\frac{3125 \cdot 40 + 1}{24} = -\frac{11.5}{24} = -.479.$

Take mom's. about "C" and consider portion of truss to right of "C".

$-V_2 \cdot 40 + H_2 \cdot 24 = 0$ $\qquad H_2 = \frac{-.3125 \cdot 40}{24} = \frac{12.5}{24} = .521.$

Member.	Unit V.Load@4'	Unit V.Load@5.	Unit V.Load@6'	Unit H.Load@4'	D.L.@4' 10210#	D.L.@5 20420#	Hor @4' 4[illegible]#	Σ Vert.D.L.	Σ D.L + Wind Load.	Max. Stress.	Member Used.
FY'	-1.000	0.000	0.000	+ 0.270	0.000	0	+ 1330	-10200	-8880	-10210	2∠s 3"×2"×3/8".
Y'X	"	+0.500	"	+ 0.885	"	+10210	+4350	+10210	+14560	+14560	2∠s 3"×2"×3/8".
Y'Z'	"	0.000	"	0.000	"	0.000	0.000	0.000	0.000	0.000	
GZ'	"	"	"	0.000	"	0.000	0.000	0.000	0.000	0.000	
Z'X	"	+0.500	"	+0.885	"	+10210	+4350	+10210	+14560	+14560	2∠s 3"×2"×3/8".
ZX	"	"	"	+ 0.500	"	+10210	+ 2175	+10210	+12385	+12385	2∠s 3"×2"×3/8".
HZ	"	0.000	"	0.000	"	0.000	0.000	0.000	0.000	0.000	
ZY	"	"	"	"	"	0.000	0.000	0.000	0.000	0.000	
YX	"	+0.500	"	"	"	+10210	0.000	+10210	+10210	+10210	2∠s 3"×[illegible] 3/8".
Y1	"	0.000	-1.000	"	"	0.000	0.000				

Stresses in M'mb's. of the Cupola.

Design of Members:

Lower Chord AN - AN'   Stress = $-217{,}370^{\#}$

American Bridge Hand book referred to.

2 ∠s - 6" × 6" × 5/8" $r = 2.7$ Gusset Pls = 3/4".

$S = 16\,000 - 70\,\frac{l}{r} = 16000 - 70 \cdot \frac{13 \cdot 12}{2.7} = 12080^{\#}$

$\frac{217370}{12080} =$ 18 □" required.

2 ∠s 6" × 6" × 5/8" have area = 14.22 □".

Add 1 plate 13" × 3/8" = 4.88 □".

Total A = 14.22 + 4.88 = 19.10 □" O.K.

Use American Bridge Hand book thru out.

Lower Chord AP - AP'   Stress = $-153455.^{\#}$

Length = 13'-0" = 156."

Use 2 ∠s 6" × 6" × 5/8".

Lower Chord AR - AR'.   Stress = $-180{,}150.^{\#}$

Length = 15'-0" = 180".

Use 2 ∠s 6" × 6" × 3/4".

Lower Chord AT - AT'   Stress = $-167{,}220.^{\#}$

Length = 14'-0" = 168"

Use 2 ∠s 6" × 6" × 11/16".

Lower Chord AV - AV'.   Stress = $-65400.^{\#}$

Length = 13'-0" = 156."

Use 2 ∠s 6" × 4" × 3/8".

Design of Members.

BN-MN-BO'-MO. Stress = +106710#

$\frac{106710}{16000}$ = 6.68 □" required.

Use 2∠s-6"×4"×5/8".

Upper Chord-Same member used thru-out.

Max tension = +94686#. Req. A = 5.92 □."

Max. Comp = -78240# L = 14' = 168."

Amer. Bridge H.B. 2∠s-6"×4"×3/8". A is OK. for tension.

ON-O'N'. No stress. Make mbr. 2∠s-2½"×2½"×3/8".

QP-Q'P'. Stress = -44960# L = 14' = 168."

Use 2∠s 3½"×3½"×7/16".

QR-Q'R'. Stress = -48300#

Use 2∠s 3"×3"×3/8".

RS-R'S'. Stress = +48090.#

Req. Area = 3.1 □" Use 2∠s 3"×3"×3/8".

ST-S'T'. Stress = -42150.#

Use 2∠s 3"×2½"×3/8".

TU-T'U' Stress = +98340#

Area required = 6.18□."

Use 2∠s 3½"×3"×5/8".

Design of Members.

UV - U'V' Stress = -27450.# Length = 3'-0" = 36"

Use 2∠s 3" x 2½" x 3/8".

VW - V'W'. Stress = -47470.# L = 14' = 168."

Use 2∠s 3½" x 3½" x ½".

W1 - W2. Stress = +41695.# Required A = 2.6□"

Use 2∠s 2½" x 2½" x 3/8".

OP - O'P.' Stress = -104670.# L = 13'-0" = 156."

Use 2∠s 6" x 4" x ½".

A1 - A2. Stress = -58820.#

Use 2∠s 3½" x 3" x 3/8".

X1 - X2. Stress = -58820.#

Use 2∠s 3½" x 3" x 3/8".

Design and Detail of Walk.

D.L on walk = 65# per sq ft.
L.L. on walk = 100# per sq. ft.
Total = 165# per sq. ft.

Width of walk = 11'-0"   Length = 20'-0"
Total W of walk = 11·20·165 = 36,300.#

$$M = \frac{1}{8} W l = \frac{36300 \cdot 11 \cdot 12}{8} = 598950''\#.$$

$$M = \frac{SI}{c} \quad \text{or} \quad \frac{I}{c} = \frac{M}{S} = \frac{598950}{16000} = 37.4.$$

Use 12" - 35# I beam.   (Car. hand book).

Total H stress is to be taken up by eye bars. These eye bars are to run from pin to pin.

PT.	H	Load	Total	H	Σ Total.
1	0.00	26340	000	4800	4800
2	0.208	38528	8010		8010
3	0.416	20420	8500		8500
4	.0.625	32355	20200	12340	32540
ΣPT.					53850

Total tension in eye bar = 53850.#

$\frac{53850}{16000}$ = 3.37 □"

Use 1 eye bar 3" x 1¼". A = 3.75 □."

All rivets will be shop, and all are in double shear or in bearing. Value of one 3/4" rivet in double shear is 10600.# Value of one 3/4" rivet in bearing on 1/2" plate is 9000.# All rivets will be designed for this bearing value.

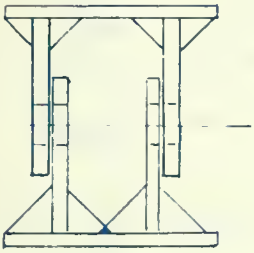
Design of Shoe

Maximum Reaction = 120960#

Assume 4" pin for rocker

Required bearing = $\frac{120960}{24000 \times 4}$ = $\frac{120960}{96000}$ = 1.26 □"

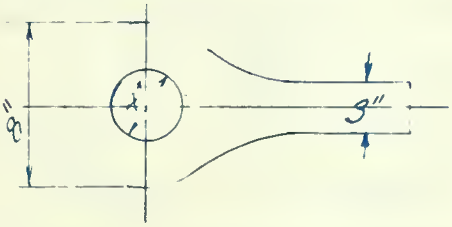
Using 2 - 1¼" metal bearings = 2.50 □" O.K.



For eye bar tie rod.

Required bearing = $\frac{53000}{24000 \times 4}$ = .6 □"

Use 1¼" eye bar O.K.



Design of Purlins.

Load per sq. ft. surface; Concrete - 50# / sq. ft.

Roofing - 5# / "

Wind - 20# / "

75# = Total.

75 × sec ϕ = 75 × 1.06 = 79.5#

79.5 + 20 = 99.5#

Wt. of purlins = 4# per sq. ft. Total = 114# per sq. ft.

Total load = 11.5 · 20 114 = 2620.#

M = $\frac{Wl}{8}$ = $\frac{2620 \cdot 20 \cdot 2}{8}$ = 78600.'#

Minimum depth = $\frac{1}{30}$ · 20 · 12 = 8."

$\frac{78600}{16000}$ = 5.35

Use 8" - 20¾# I beam.

Design of beams:-

Mk. B. L = 20'-0"

$w = (L.L. + D.L.) = 6.66 \cdot 475 = 3170\#$ per lin. ft.

D.L. weight of beam (assumed) = 300# per ln. ft.

Total = 3470# per lin. ft.

$V = 3470 \cdot 10 = 34700\#$

$v' = \frac{V}{b'd}$ $b'd = \frac{34700}{133} = 260$ □" required.

Use beam 25" as b' and d = 12".

$\frac{25 \cdot 12}{144} \cdot 150 = 310\#$ ∴ Assumed DL. is OK.

$M = \frac{12}{10} \cdot 3470 \cdot 400 = 1{,}665{,}000''\#$

$A = \frac{1665000}{18000 \cdot 7/8 \cdot 25} = 4.23$ □"

Use 5 – 1" ϕ rods.

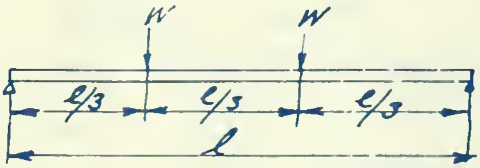
Turn up 2 in 1 direction and 3 from other direction as on 2nd floor.

Make beam same as 2nd floor beam.

Design of girder. Mk "C" L = 20'-0"

Loads at 3rd points each = 69400#

$B.M.(\text{due to loads}) = \frac{69400 \cdot 20}{3} \cdot \frac{2}{3} \cdot 12 = 1{,}850{,}000''\#$



$W = 69400\#$

$\frac{L}{3} = \frac{20}{3} = 6.66'$

$M_{(\text{DL. weight of girder})} = \frac{12}{10} \cdot 700 \cdot \overline{20}^2 = 336000''\#$

Total $M = 2{,}186{,}000''\#$

$V = 700 \cdot 10 + 69400 = 76400\#$

$\frac{76400}{133} = 575$ □" required.

Make beam 16" × 36" b' = 16; d = 36"

$\frac{37\cdot16}{144}\cdot150 = 620^{\#}$ ∴ D.L. is O.K.

$b = 8t + b' = 48 + 16 \cdot 64''$.

$A = \frac{M}{f_s jd} = \frac{2.186{,}000}{18000\cdot 7/8 \cdot 36} = \frac{2186}{81.7} = 3.85\,\square''$

Use 10 – 5/8" φ rods.

$R = \frac{M}{bd^2} = \frac{2186000}{64\cdot36} = 27.$ $\frac{t}{d} = \frac{6}{36} = .1667.$

Plate XI $f_c = 320$ $K = .2$ $j = .91$ All O.K.

Over Support.

$M = -2186000''^{\#}$

$R = -\frac{2186000}{16\cdot36^2} = 108$ $f_c = 810^{\#}$

$\frac{810-700}{810} = \frac{110}{810} = .136$ % reduction.

.5% = percent compression steel needed.

$.005\cdot16\cdot36 = 2.88\,\square''$ Compression steel needed.

Use same steel as at center of beam.

Bond Stress:–

$\mu = \frac{V}{\Sigma\phi jd} = \frac{76400}{4\cdot 7/8\cdot 36\ 5/8\cdot 10} = 97^{\#}$ O.K.

Shear:– Stirrups:–

$v = \frac{V}{b'd} = \frac{76400}{16\ 36} = 130^{\#}$

$v' = 130 - 40 = 90^{\#}$ to be taken by steel.

Make $s = 5''$.

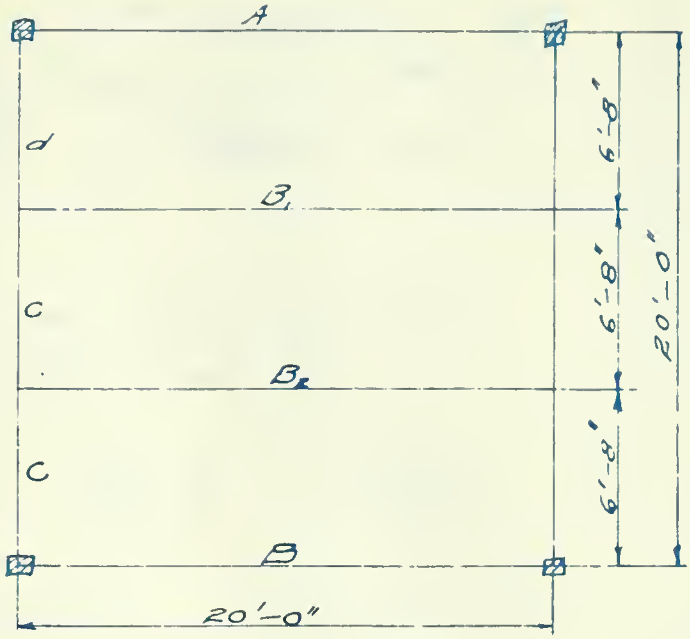
$P_s = v'b's = 90\cdot16\cdot5 = 7200^{\#}$

$4\,Af_s = 7200.$

$A = \frac{7200}{4\cdot12000} = .15\,\square''$

Use 1/2" φ rods as stirrups

Bend as shown on detail drawing.



Second Floor

Design of Floor slab.

L.L. = 100# per sq. ft.

D.L. = 50# per sq. ft.

Total = 150# per sq. ft.

$$M = \frac{12}{10} w l^2 = \frac{12 \cdot 150 \cdot \overline{20}^2}{10} = 72000''\#$$

$b = 12''$ $\quad f_s = 18000\#$ per sq. in.

$f_c = 700\#$ per sq. in.

$R = 113.$

Table III Turneaure + Maurer.

$p = .0072$

$$M = Rbd^2 \qquad d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{72000}{12 \cdot 113}} = 5.3''$$

D.L. too small.

L.L. = 100# per sq. ft.

D.L. = 80# per sq. ft.

Total = 180# per sq. ft.

$M = \frac{12}{10} \cdot 180 \cdot \overline{20}^2 = 86400$ '#

$d = \sqrt{\frac{M}{bR}} = \sqrt{\frac{86400}{12 \cdot 1\text{[illegible]}}} = 6.3''$

Make t = 7" Assumed D.L. O.K.

$A = pbd = .0072 \cdot 12 \cdot 6.3 = .55 \,\square''$

Use 5/8" φ 8" O.C.

Shear:—

$v = \frac{V}{bd} = \frac{180 \cdot 20}{2 \cdot 12 \cdot 7} = 21.4\#$ O.K.

Bond Stress:—

$\mu = \frac{V}{\Sigma \phi j d} = \frac{1800}{\frac{3}{12} \cdot .9 \cdot 7 \cdot 4\frac{5}{8}} = 89\#$ O.K.

Design of Beams:—

Beam Mk. "A" Interior beam.

L.L. = 20 · 100 = 2000# per lin. ft.

D.L. = 20 · 80 = 1600# per lin. ft.

D.L. (weight of beam) = 300# per lin. ft.

Total = 3900 # per lin. ft. = ω.

$V = \frac{\omega l}{2} = \frac{3900 \cdot 20}{2} = 39000\#$

$\frac{39000}{133} = bd = 293 \,\square''$

Make b = 12" d = 25" bd = 300 □"

$b = 8t + b' = 8 \cdot 7 + 12 = 68''$

$\frac{12 \cdot 25}{144} \cdot 150 = 300\#$ Assumed D.L. O.K.

$A = \frac{M}{f_s j d} = \frac{\frac{12}{10} \omega l^2}{18000 \cdot .9 \cdot 25} = \frac{1870000}{18000 \cdot .9 \cdot 25} = 4.62 \,\square''$

Use 5 - 1" ϕ rods.

$p = \frac{A}{bd} = \frac{4.62}{68 \cdot 25} = .0027$

$\frac{t}{d} = \frac{7}{25} = .28.$

$R - \frac{M}{bd^2} = \frac{1870000}{68 \cdot 625} = 43.9.$

$f_c - 400^{\#}$ $K = .24$ $j = .90$

All values used are O.K.

Values from T.+M. Plate XI.

Stirrups:—

$V' = \frac{V}{bd} = \frac{39000}{12 \cdot 25} = 130.^{\#}$ $130 - 40 = 90^{\#} = v'$ $b = 12.$

$P_s = v'bs = 90 \cdot 12 \cdot 5 = 5400^{\#}$ $s = 5''$

$2Af_s = 5400$ $A = \frac{5400}{24000} = .23 \square''$ Use 5/8" ϕ rods.

Bond Stress:-

$\mu = \frac{V}{\Sigma \phi jd} = \frac{39000}{5 \cdot 4 \cdot 9.25} = 87^{\#}$ O.K.

B.M. @ Support = $-1870000.'^{\#}$

$R = \frac{M}{b'd^2} = \frac{1,870,000}{12 \cdot 625} = 250.$

$p = \frac{4.62}{12 \cdot 25} = .0154.$

$j = .85$ $K = .50$ (Turneaure + Maurer, Pl. III.)

$f_c = \frac{2M}{Kj\,b'd^2} = \frac{3740000}{.5 \cdot .85 \cdot 12 \cdot 625} = 1170.^{\#}$

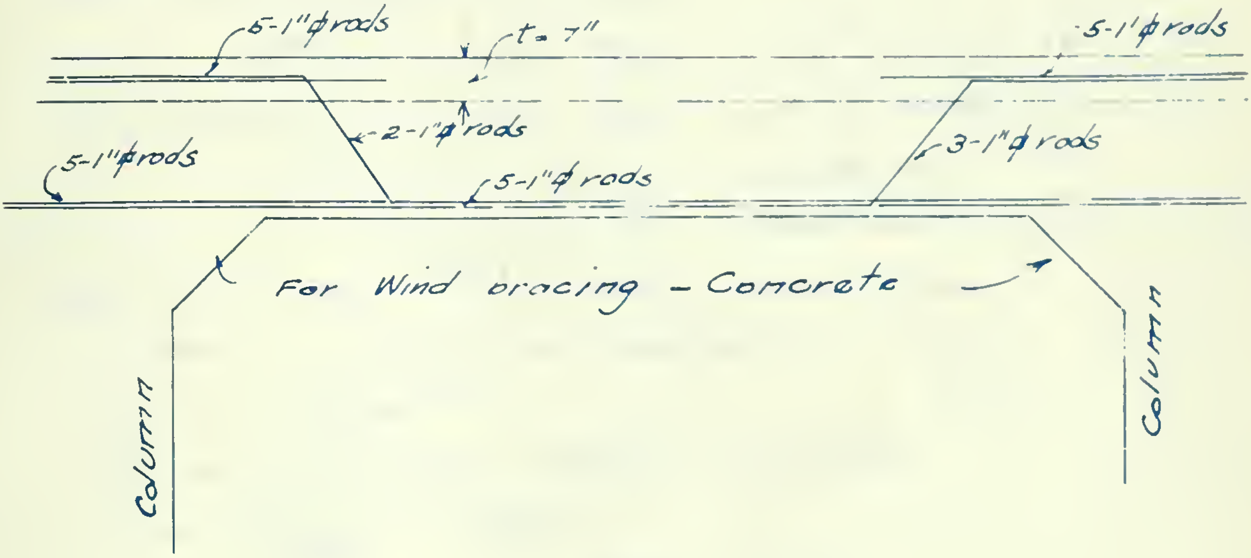
$\frac{1170-700}{1170} = \frac{470}{1170} = 40\% =$ percent reduction.

Percent compression steel = $.0150 \square\%$.

$.015 \cdot 12 \cdot 25 = 4.5 \phi''$

Use same steel as at center of beam.

Sketch showing steel.



Beams B_1 and B_2 omitted on 2nd floor.

First Floor Design:-

Design of floor slab.

L.L. = 400# per sq. ft. $L = \frac{20}{3} = 6.66'$

D.L. = 70# per sq.ft.

Total = 470# per sq. ft.

$$M = \frac{12}{10} wl^2 = \frac{12 \cdot 470 \cdot \overline{6.66}^2}{10} = 25100''\#$$

$f_c = 700\#$

$f_s = 18000\#$

$p = .0072$

$R = 113$

$$d = \sqrt{\frac{M}{bR}} = \sqrt{\frac{25100}{12 \cdot 113}} = 4.3'' \text{ or } 4\tfrac{1}{2}''$$

Make $t = 6''$

$\frac{6}{12} \cdot 150 = 75\#$ Assumed D.L. O.K.

Make $d = 4.5''$ $b = 12''$

$A = pbd = .0072 \cdot 45 \cdot 12 = .389 \square''$

Use ½" φ rods 7" O.C.

Design of Columns.

Interior Columns. Mk. ②.

L.L. $= 100^{\#}/\text{sq. ft.}$ or $20 \cdot 100 = 2000^{\#}$ per lin. ft.

D.L. $= 80^{\#}/\text{sq.ft.}$ or $20 \cdot 80 = 1600^{\#}$ perlin. ft.

D.L. beam $= \underline{300^{\#}}$ per lin.ft.

Total $= 3900^{\#}$ per lin. ft.

$3900 \cdot 20 = 78600^{\#} =$ load from floor.

Assume $\underline{4500^{\#}}$ as weight of column.

$P = 83100^{\#}.$ $p = .01.$

$$P = 400A(1+14p) = 456A = 83100^{\#}$$

$$A = \frac{83100}{456} = 183 \square''$$

$d = 15.3$ Make $D = 18''$

$A_s = Ap = 183 \cdot .01 = 1.83 \square''$

Use $8 - \frac{1}{2}''$ ϕ rods.

Column Mk. ①

Load from floor $= \frac{78600}{2}$ or $39300^{\#}$.

Load from roof truss (D.L.+L.L.+W.L.) $= \underline{120\,960^{\#}}$

Total $= 160260^{\#}$

Wt. of column (assumed) $= \underline{5800^{\#}}$

Grand Total $= P = 166060^{\#}$

Use $p = .015$ $p_s = .01$

$$P = 500A(1+14p)(1+35p_s) = 816.5A = 166060$$

$$A = \frac{166060}{816.5} = 202 \square''$$

$d = 16.1''$ Make $D = 20''$

Least $D = \frac{L}{12} = \frac{18 \cdot 12}{12} = 18.''$

$A_s = Ap = .015 \cdot 202 = 3.06 \square''$

Use $8 - \frac{5}{8}''$ ϕ rods for vert. reinforcing.

Let d_1 = diam. of spiral reinforcing rods.

i = pitch = $1\frac{1}{4}$"

$$d_1^2 = \frac{p_s\, i\, D}{\pi} = \frac{.010 \cdot 1.25 \cdot 20}{3.14} = .0398$$

$d_1 = .20"$

Use $\frac{3}{8}$" ϕ rods for spiral reinforcing.

Design of column Mk.③.

Load from floor = 39300#

Load from Truss = 120960#

Total = 160260#

Wt. of column = 6500#

Max. Reaction of Girder = 18680#

Grand Total = P = 185440#

Use $p = .015$. $p_s = .01$.

$P = 500A(1+14p)(1+.05p_s) = 816.5A = 185440$#

$$A = \frac{185440}{816.5} = 227 \square"$$

$d = 17"$ Make $D = 20"$

$$\text{Least } D = \frac{h}{12} = \frac{18 \cdot 12}{12} = 18"$$

$A_s = A_p = .015 \cdot 227 = 3.4 \square"$

Use 8 - $\frac{3}{4}$" ϕ rods for vertical reinforcing.

$$d_1^2 = \frac{p_s\, i\, D}{\pi} = \frac{.01 \cdot 1.25 \cdot 20}{3.14} = .0398$$

$d_1 = .2"$ Use $\frac{3}{8}$" ϕ rods for Spiral.

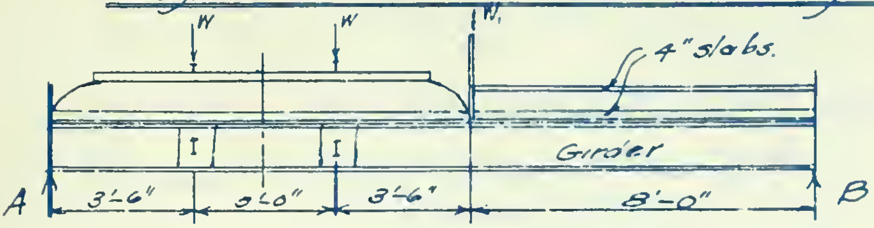
Design of Column Mk.④.

Total load = Reaction from Girder + Wt. of column.

Reaction (max.) = 34520#

Make this column same as interior column Mk.②.

Design of beams and Girder to carry St. Cars.



Assume ballast and ties = 100# per sq. ft.

Assume D.L. weight of slab = 50# " " ".

Total = 150# per sq. ft.

$M = \frac{12}{10} wl^2 = \frac{12 \cdot 150 \cdot 11^2}{10} = 21780.''\#$

$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{21780}{113 \cdot 12}} = 4.''$ Make t = 5"

This slab is to carry the ties and ballast.

Ballast plus ties = 100# per sq. ft.

$12 \cdot 100 = 1200\#$ = weight ties + ballast per ft. track

Rails = 60# per lin. ft. of track.

Stringers = 100# " " " " "

Slab = 600# " " " " "

Total = 1960# " " " " ".

$\frac{1960}{2} = 980\#$ " " " " stringer.

$M_{(DL)} = \frac{12}{10} wl^2 = \frac{12 \cdot 980 \cdot 20^2}{10} = 470000 ''\#$

L.L. = 2400# per lin. ft. of track. (De Pontibus Pl. VI)

= 1200# " " " " stringer.

$M_{(LL)} = \frac{12 wl^2}{10} = \frac{12 \cdot 1200 \cdot 40}{10} = 576000.''\#$

Total = $1046000.''\#$

$\frac{1046000}{16000} = 65.1 = \frac{I}{C}.$

(Car. Pg. 142.)

Use 15" - 55# I beam as stringer.

Design of Girder:—

Refer to sketch above.

$W = \frac{(980 + 1200) \cdot 20}{2} = 21800\#.$

$W_1 = \frac{8}{12} \cdot 150 \cdot 8 \cdot 10 = 8000\#.$

Assume Girder at 80# per lin. ft.

$M_{(DL.\ Girder)} = \frac{80 \cdot 20^2}{8} \cdot 12 = 48000.^{''\#}$

$Ra_{(Con.\ Loads)} = \frac{8000 \cdot 8 + 21800 \cdot 11.5 + 21800 \cdot 16.5}{20} = 33720.^{\#}$

$Rb_{(Con.\ Loads)} = (43600 + 8000) - 33720 = 17880.^{\#}$

$Ra_{(Girder)} = \frac{80 \cdot 20}{2} = 800.^{\#}$

$Rb_{(Girder)} = 800^{\#}.$

Total $Ra = 34520.^{\#}$ Total $R_b = 18680.^{\#}$

$Max.\ M_{(Con.\ Loads)} = (33720 \cdot 85 - 21800 \cdot 5)12 = 2136000.^{''\#}$

Total Mom. $= 2{,}184{,}000.^{''\#}$

$\frac{2184000}{16000} = 136 = \frac{I}{c}.$ (Car. Pg. 142)

Use 20″ – 80# I beam for Girder.

Design of footings.

Footing under column Mk ②. $P = 83100^{\#}$ $a = 18''$

Saf load on 1 pile = $\frac{2Wh}{d+.1}$

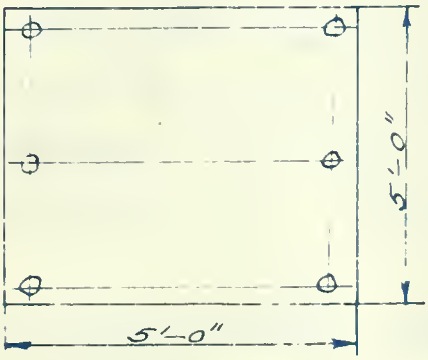
W = Weight of hammer in pounds.

h = drop of hammer in feet.

d = penetration of pile in inches (last blow)

$W = 5000^{\#}$ $h = \frac{34}{12} = 2\frac{5}{6}'$ $d = .9''$

Safe load = $\frac{2 \cdot 5000 \cdot 2.833}{.9 + .1} = 28330^{\#}$ per pile.



$l = 5'-0'' = 60''$ $a = 1.5'$

load on column = $83100.^{\#}$

Weight of footing = $\underline{6000}^{\#}$

Total = $89100^{\#}.$

$\frac{89100}{28330} = 4$ Piles needed.

Use 6 piles as shown in sketch.

$\frac{6 \cdot 28300}{25} = w = 6800^{\#}.$

$v_p = .120^{\#}$ $d = \frac{(l^2 - a^2)w}{4aj v_0} = \frac{(25 - 2.25)6800}{4 \cdot 18 \cdot .9 \cdot 120} = 20.2.$

Make $d = 21''$

$M = [\frac{1}{8} a(l-a)^2 + \frac{3}{40}(l-a)^3]w$

$= (\frac{1}{8} \cdot 1.5 \cdot \overline{3.5}^2 + \frac{3}{40} \cdot \overline{3.5}^3) 6800$

$= 5.54 \cdot 6800 = 37700'^{\#}$ or $452400''^{\#}$

$A = \frac{M}{f_s j d} = \frac{452400}{18000 \cdot .9 \cdot 21} = 1.33 \square''$

Use 10 - ½" φ rods - to develop Bond Stress.

Bond Stress:-

$\mu = \frac{V}{\Sigma\phi j d} = \frac{\frac{1}{4}(l^2 - a^2)w}{\Sigma\phi j d} = \frac{22.75 \cdot 6800}{4 \cdot \frac{1}{2} \cdot 10 \cdot .9 \cdot 21} = 100^{\#}$ O.K.

Diagonal Tension:-

$V_{all} = [l^2 - (a+2d)^2]w = [25 - (1.5+3.5)^2]6800 = 0$ O.K.

Footing under column ④ will not be calculated as the drawing shows that the footing will be far greater than it need be owing to the method of construction. The column needs but a small footing.

Also the footing under columns Mk. ① will not be calculated as they rest on the stone between the two outside rows of piles. See drawing for details.

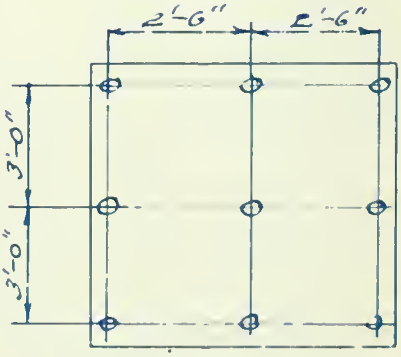
Footing under Column Mk. ③.

$P = 185000\#$ $a = 20'' = 1.66'$

Safe load per pile $= 28330\#$

185000# = load on column.
12000# = weight of footing.
197000# = total load on piles.

$\frac{197000\#}{2830} =$ 7 piles needed.



Use 9 piles as shown in sketch.

$l = 8'\text{-}0'' = 96''$

$9 \cdot \frac{28300}{64} = 3900\# = w.$

$v_p = 120\#$ $d = \frac{(l^2 - a^2)w}{4aj\,v_p} = \frac{(64 - 2.76)3900}{4 \cdot 20 \cdot .9 \cdot 120} = 27.7''$

Make $d = 35''$

$M = \left[\frac{1}{8}a(T-a)^2 + \frac{3}{40}(l-a)^3\right]w$

$= \left[\frac{1}{8} \cdot 1.66 \cdot \overline{6.34}^2 + \frac{3}{40} \cdot \overline{6.34}^3\right] 3900.$

$= (8.38 + 13.1)\,3900 = 1070000.$'#

$12 \cdot 1070000 = 12840000$ "#

$A = \frac{12840000}{18000 \cdot .9 \cdot 35} = 22.5\,\square"$

Use 20 - 3/4" ϕ rods to develop bond Stress.

Bond Stress:—

$u = \frac{V}{\Sigma o\, jd} = \frac{(64 - 27)\,3900}{20 \cdot \frac{3}{4} \cdot \pi \cdot .9 \cdot 35} = 125\#$ O.K.

Diagonal Tension:—

$V_{dt} = [c^2 - (a + 2d)^2]\,3900$

$= [64 - (1.66 + 3.3)^2]\,3900$

$= (64 - 21.8)\,3900 = 164000.\#$

$u = \frac{V_{dt}}{4(a+2d)\,jd} = \frac{164000}{4 \cdot 90 \cdot .9 \cdot 35} = 14.6\#$ O.K.

$b = a + 2d + \frac{1}{2}(c - a + 2d)$

$= 20 + 70 + \frac{1}{2}(96 - 90) = 93"$

Steel in footing spread over 93"

DESIGN OF A REINFORCED CONCRETE PIER

SPECIFICATIONS

General:-

The work hereinafter specified shall consist in furnishing, delivering and building in place all temporary work, and in furnishing all materials, tools, labor and all appliances and appurtenances required in the performance of all necessary operations for the complete construction and erection of the freight and recreation sheds forming part of the recreation pier to be located at the lake end of Twenty Second Street.

The accompanying plans form part of the specifications, and in all cases figured dimensions are to be used in preference to scaled measurements.

Anything shown on the plans and not specified, or specified and not shown, shall be executed as though both fully shown and specified.

The plans furnished should be carefully checked by the contractor before beginning work. Should any errors or discrepancies be found, the attention of the engineer in charge shall be called to same.

If any discrepancy should be found between the plans and specifications the judgment of the Commissioner shall be decisive thereon. Should the quantities called for by the plans be diminished only the actual quantities furnished shall be paid for at the contract price.

Bidders are requested to carefully examine the site of the proposed work, the plans and the contents of these specifications. No changes in either plans or specifications will be permitted under any circumstances, unless the same shall have been ordered in writing by the Engineer in charge. No claims on oral orders for changes will be allowed. The contractor shall arrange his work to conform with all the ordinances in force in the City of Chicago.

The contractor hereby agrees that all fees for any patent, invention, article or arrangement that may be used upon or in any

manner connected with any part of the structure as called for by these specifications shall be included in the price as bid, and the contractor further agrees to indemnify and save harmless the City, and defend any claims, suits and actions at law that may be brought against the City on account of any patent, invention, article or arrangement that may be used by the contractor in connection with any part of the work to be done by virtue of these specifications.

At the completion of this part of the pier the contractor shall remove all boxing, falsework, earth or other unsightly material caused by his operations, and shall leave the grounds and shores of the lake in as good condition as they were before beginning work.

If the contractor shall find it necessary to make detail drawings he shall submit, after signing the contract and before beginning work covered by these detail drawings,

to the Engineer in charge two blue-print copies of each of the drawings and plans for approval, and, after they are finally approved on tracings, at least six (6) prints of each of such approved plans shall be furnished the City of Chicago free of cost. No alterations of approved plans will be permitted to be made by the contractor without the written consent of the Engineer in Charge.

All drawings submitted shall be of a uniform size with a border margin of one-half inch all around.

The approval of plans by the Engineer in Charge will not relieve the contractor from the responsibility and consequences of any error thereon.

Whenever it is necessary to give directions, and the contractor is not present on any part of the work, orders will be given by the Engineer in charge to the foreman or overseer who has charge of the particular work in relation to which orders are given, and who

shall receive and obey the orders.

The contractor shall give personal superintendence to the work and shall keep a competent foreman constantly on the ground. He shall carefully lay out his work and be responsivle for all mistakes made therein.

The contractor shall afford the Engineer in charge and his subordinates every facility to inspect the work in safety.

The contractor shall cooperate with all other contractors working upon or about the pier and shall carry his work in subh manner as not to hinder or delay any other contractor in the performance of his work.

The contractor shall provide all necessary safeguards and protection against accident, injury and damage to persons and property during the progress of his work, and shall be solely responsible for any loss, damage or injury that may happen to any work, materials and property, and to any person whomsoever, whether workman, or otherwise, and

shall keep and save the city of Chicago harmless therefrom.

The contractor shall use every precaution to brace and otherwise support and secure the walls, floors, and roof during the construction of the work, and shall be responsible, and not the City of Chicago, for any loss or damage that may be sustained to the amount paid him by the City of Chicago on account of same, loss or damage by fire excepted.

The successful bidder will be required to execute and deliver a bond with good and sufficient sureties, to be approved by the Commissioner of Public Works, in such amount as shall not only be adequate to insure the performance of the work in the time and manner required in the contract, but also to save and indemnify and keep harmless the City of Chicago against all liabilities, judgments, costs and expenses which in any wise may accrue against said city in consequence of the granting of the contract or for the doing of the work thereunder, or

which may in any wise result from the carelessness or neglect of the contractor or his agents, employes or workmen, and when due notice has been given of the pendency of such suit, such judgment shall be conclusive against the contractor and his sureties on such bond, not only as to the amount of such damage, but as to their liability; and conditioned also for the payment of all claims or demands whatsoever, which may accrue to each and every person who shall be employed by such contractor or any assignee or sub-contractor of such contractor in or about the performance of the contract.

Any bidder to whom the contract is awarded who shall fail to appear at the office of Department of Public Works, either in person or by his agent, within two days after being addressed through the post office of the City of Chicago, or shall not within three days

furnish the required security, shall forfeit his claim to the work. No contractor will be allowed to sublet the whole or any part of his work, or make an assignment of the moneys to be paid him without special permission in writing from the Commission of Public Works.

No bids will be accepted from or contract awarded to any person, firm or corporation that is in arrears or in default of the City of Chicago upon any debt or contract, or that is a defaulter, as surety or otherwise, upon any obligation to said city.

The right is hereby reserved to the Commissioner of Public Works to finally decide all questions arising as to the proper performance of the work and in case of improper construction or of noncompliance with the contract in any manner, the Commission of Public Works may suspend such work at any time, or may order the partial or entire reconstruction of said work, if improperly done, or declare

the contract forfeited, and may relet the same. He may also adjust the difference of damages or price, if any, which the contractor, failing to properly construct such work, in case of default, should pay to the City of Chicago according to the just and reasonable interpretation of said contract. In all such matters the decision of the Commissioner of Public Works or the Engineer in charge shall be final between the parties thereto.

It is understood and agreed that no claim whatever will be made or allowed for extra work or material unless some changes or additions to the work herein specified or shown on the accepted plans or drawings requiring additional outlay by the contractor shall first have been ordered in writing by the Commissioner of Public Works. The Commissioner of Public Works shall be the sole judge of whether such extra work as may be ordered shall

be work other than that required to make the structure complete and perfect for the purpose designed, notwithstanding previous acceptance and approval of plans and specifications at the time of the signing of the contract.

In the event of such work being decided to be additional work it shall be paid for whenever possible at the rate of unit prices as stipulated in the bid; or, when this cannot be done, at the rate of prices fixed by the Commissioner of Public Works, whose decision shall be final.

It is understood, however, that for all extra work to be ordered in writing by the Commissioner of Public Works, the express authority of the City Council for such extra work and for the expenditure of the amount to be paid therefor, must have been previously procured.

The contractor must deliver to the Commissionr of Public Works on or before the tenth

day of each month a written statement of amount of claims, if any, for extra work done and extra materials furnished during the previous month, or for extra expense incurred from any cause whatever; otherwise claims for extras during that month will be forfeited and waived.

Monthly estimates will be made by the Commissioner of Public Works of the value of the work done, and material delivered, erected and accepted, and each month, a voucher for 85 percent of the value of the work done and material delivered, erected and accepted the previous month will be issued, the remaining 15 percent to be reserved until the completion and final acceptance of the work by the Commissioner of Public Works.

These specifications and the plans shall be incorporated in and become a part of the contract.

DESIGN OF A REINFORCED CONCRETE PIER

The Commissioner of Public Works reserves the right to reject any or all bids, and to award the contract to that bidder whose guarantees of capacity, efficiency and workmanship most fully meet, in his judgment, the requirements of these specifications.

Bids, which are palpably unbalanced and contain price bids obviously below the cost for which the work or material in question can be done or delivered, will be rejected.

DESIGN OF A REINFORCED CONCRETE PIER

Cement:-

The cement shall be a first-class Portland cement (unless otherwise specified) of a standard brand made by a manufacturer of established reputation, and shall meet the following requirements.

1. Before any cement will be allowed to be used, the brand and name of the maker must be submitted to and receive the approval of the Engineer, and no cement will be permitted to be used that is not in all respects satisfactory to him. It is understood that such approval merely covers the selection of the brand; that the cement itself may be rejected if it fails to meet the requirements herein specified.

2. Only one brand of cement shall be allowed upon the works, except by special permission of the Engineer.

3. In order to allow ample time for the inspection and testing of cement, it shall be stored in a suitable house or houses provided by the Contractor for that purpose. The houses

shall be sufficiently large so that the different lots of cement can be kept separate and readily accessible. The floor shall be raised above the ground so as to keep the cement dry, and the sides and roof shall be water-tight to protect the cement from rain or the injurious effects of the elements. The cement shall be stored in such manner as to permit easy access for proper inspection, sampling and identification of each shipment. No cement shall be used that has not been in the storehouse for at least two weeks.

4. All cement used on the work shall be subject to inspection and such rigorous tests as shall be ordered by the Engineer, and the contractor shall provide every facility to assist in the inspection and sampling of the cement for testing, repeated as many times as are deemed necessary by the Engineer.

Tests may be made both at the place of manufacture or storage, and at the site of the

work if the Engineer deems wise, and he shall have the liberty at all times to inspect the materials, process of manufacture and daily laboratory records of analyses and tests at the cement works.

5. When used in the work, the cement shall be free from lumps and partially or wholly set cement, and in all respects satisfactory to the Engineer. Cement found at any time to be unsatisfactory-before, during or after its placing in the work -- shall be subject to rejection, even to the extent of taking down masonry or other work in which unsatisfactory cement may have been used. Cement rejected on the work shall be immediately removed from the site.

6. All tests shall be made in strict accordance with the methods proposed by the Special Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society on January 17, 1912,

with all subsequent amendments thereto. The acceptance or rejection shall be based on the requirements named in these specifications.

Sand, Broken Stone and Gravel:-

The sand used shall be coarse, clean and sharp torpedo sand, free from all clay, loam or gravel, and shall be screened, and of a quality approved by the Commissioner of Public Works or his representatives.

The stone or concrete shall be of a quality approved by the Commissioner of Public Works, broken into angular pieces of a size small enough to pass through a ring one and one-half (1½) inches in diameter, and shall be entirely free from dust, sand, dirt or any foreign substance.

Large gravel of a quality approved by the Commissioner of Public Works may be used for concrete if thoroughly washed and broken into angular pieces of a size given for usual stone. This gravel after being washed, broken and cleaned may be mixed at the stone yard with approved torpedo sand in the proportion prescribed for the concrete, provided this mixing is done in a manner satisfactory to the Commissioner of Public Works.

DESIGN OF A REINFORCED CONCRETE PIER

Reinforcing Steel:-

The reinforcing steel shall be the common round or square bar as detailed on the plans.

The steel to be used for these bars must be uniform in quality, may be made by the Bessemer process, and must have an elastic limit of 50,000 to 60,000 pounds per square inch. Finished bars must stand bending cold 90 degrees to a radius of five times their diameter.

All bars must be free from paint or oil before being placed in the concrete. All rust scales must be removed.

All reinforcing steel shall be placed in its proper position and securely held by wiring and other means, well in advance of the concreteing.

Special care must be taken in placing the steel for the second floor. The bars are

at least one and one-half ($1\frac{1}{2}$) inches from the finished face unless otherwise specified.

After the reinforcing steel is in place it shall be inspected and approved by the engineer in charge before concreteing may commence.

Necessary care must be exercised in placing the beam reinforcing. The rods must be properly spaced and the stirrups held firmly in position.

DESIGN OF A REINFORCED CONCRETE PIER

Portland Cement Concrete:-

Portland cement concrete shall be used in piers, and outer retaining wall and shall be of the following proportions:

One (1) part of Portland cement, three (3) parts of sand and five (5) parts of broken stone, or gravel, same stones of a size small enough to pass in any direction through rings ranging from one-half (1/2) to one and one-half (1½) inches in diameter. This mixture shall be used with such an amount of water that it just quakes under ramming, and shall be placed in the forms in layers of six (6) inches.

For the reinforced concrete the following proportions shall be used one (1) part Portland cement, two (2) parts sand and four (4) parts crushed stone or gravel of a size small enough to pass in any direction through rings ranging from one-half (½) to one (1) inch in diameter. This concrete shall be used rather wet, and if placed by the gravity method care

must be taken that the mixture is well spaded and churned in placing.

All concrete to be used in the structure shall be mixed in batch mixers of a type approved by the Commissioner of Public Works and operated by steam or electricity.

The ingredients shall be placed in the machine in a dry state, in the volumes specified, and then be thoroughly mixed, after which water shall be added and the mixing continued until the wet mixture becomes a uniform mass. As soon as the batch is mixed, it must be deposited in the work without delay. It shall be conveyed to place in such a manner that there shall be no distinct separation of the different ingredients or, in case where such separation inadvertently occurs, the concrete shall be re-mixed before placing. Any concrete which has set before placing shall be rejected.

All concrete shall be thoroughly tamped, rammed and contracted until water appears on

top. The tamping between the reinforcing bars shall be done most carefully with ordinary iron railway tamping bars.

When placing fresh concrete upon an old concrete surface, the latter shall be cleared of all dirt and scum, and thoroughly wetted.

Next to the forms on the lake side of the outer retaining wall where the masonry will be exposed to the weather the concrete shall be carefully hand spaded with such spading tools as recommended and approved by the Commissioner of Public Works, so that the stones are forced back and there shall be perfect and smooth surfaces next to the forms.

The entire floor area as shown on the plans is to be trowelled to a smooth and even surface in a neat and workmanlike manner. No two coat work is permitted so rough concrete must be surfaced as the work progresses.

The contractor shall keep all concrete wet by sprinkling with water until the cement is sufficiently set.

No concrete shall be laid when the temperature of the atmosphere is below plus 30 degrees Fahrenheit, except by special permission from the engineer in charge.

Piling and Fill:-

Piles for foundation shall be Norway Pine, or white oak, or of any other kind of wood which is satisfactory to and approved by the Commisioner of Public Works, and the engineer in charge. These piles to be sound and straight, not less than fourteen (14) inches at the butt and not less than eight (8) inches at the small end inside the bark, with uniform taper. If necessary, these piles shall be provided with standard pile shoes, of make acceptable to the engineer in charge and to the Commissioner of Public Works. If found necessary piles are to have a metal cap set over the pile in driving to prevent brooming.

These piles shall be accurately spaced and located according to the foundation plan. Ranges are to be set up along the shore line the same to be used to locate the position of the pile bents.

It is necessary that the outer line of piling be driven first and the outer retaining wall be constructed upon them.

The sheet piling is to be accurately placed as shown on the plans, same to be the standard Lackawana Steel Sheet Piling.

After the construction of the outer wall the inner bents of piles may be driven and fill commenced. This fill is to be a sluiced fill, a sand sucker to be used for placing the same. Fill to be carried up to proper grade.

Steel:

All steel shall be uniform in quality and made by the open-hearth process in accordance with the "Specifications for Material and Workmanship for Steel Structures," adopted in 1903 by the American Railway Engineering and Maintenance of Way Association, and amended March, 1904, by the same Association, in relation to paragraphs 9, 13, 16 and 33. These specifications, thus amended are herein called "Standard Specifications".

The elastic limits of structural and rivet steels must not be less than one-half of the desired ultimate strengths, given in paragraphs No. 2 of the Standard Specifications.

The ductility of the metal must be such that a punched hole for a 3/4 inch rivet, the center of which is not more than one and one-half ($1\frac{1}{2}$) inches from the sheared or rolled edge of the piece, may be enlarged by drifting to a diameter 50 percent, greater than the original hole without cracking the specimen at any point.

Cast Iron:

Cast iron must be the best quality of soft gray iron. The castings must be free from flaws, ragged edges, or any other defects impairing their efficiency or appearance; and bars of a section one (1) inch square, placed four (4) feet eight (8) inches between supports, must be strong enough to bear a weight of five hundred (500) pounds placed half way between supports, when tested in the rough bar.

Steel:

All workmanship must be first-class in every respect and in accordance with the "Standard Specifications," unless other wise called for, either in the following paragraphs or on the accompanying plans.

General reaming of rivet holes in the sense of paragraphs 61 to 63 of the "Standard Specifications" is required.

Sheared edges and ends shall be planed off at least 1/4 inch, where planing is required or indicated in plans, or where edges of plates and shapes exposed to view are not neatly and accurately sheared.

Joints in truss members shall be neatly milled. Bases and gusset plates and connection angles, shall be milled where ever they take bearing.

Particular care shall be taken in boring true to gauges, smooth and straight the holes for the connecting pin at the junction of the two halves of the arches.

Shop rivets, when practicable, shall be driven by a direct acting machine capable of holding the rivet until the upsetting is completed.

No inaccurate or otherwise defective work will be accepted under any circumstances in connections, joints, or riveted work.

Standard gauge distances as given in the Carnegie Hand Book are to be used, and the specifications for minimum and maximum rivet spacing there given are to be followed.

Eye-bars shall be of the standard section as given in the Carnegie Hand Book. Screw ends shall be upset to such diameter as to insure breaking in the body of the bar if tested to destruction. All screw ends shall have truncated V section threads, U.S.Standard.

Forms and Falsework:-

The contractor shall at his own risk construct all necessary falsework and forms, furnishing all material, labor and appurtenances for the same. The outer retaining wall may be cast in sections facilitating the use of one or two standard forms, using same over and over. Care must be taken in re-using forms that the forms are thoroughly cleaned, leaving the surface of the concrete clean and smooth.

The contractor must in placing his forms cooperate with the plumber and steam fitter and allow them to place their pipe conduits and chases before the concrete is poured.

The forms in general shall be of dressed lumber, perfectly fitted and with hair joints. For the foundation two inch lumber is to be used. For the beams and girders two inch lumber is preferred, however with proper bracing inch lumber may be used.

Pavement:-

The roadway is to be filled to proper grade and the twelve inch slab of concrete, reinforced as shown on plans, shall be constructed. The surface of this floor shall be float finished and when properly set a layer of sand three and one-half (3½) inches thick shall be spread, upon which the paving blocks are to be set.

When the foundation for the paving blocks is thus being prepared and before any blocks are laid the rails for the railroad tracks shall be put in their proper places. After this has been done the paving shall be continued and completed as specified in the following paragraphs.

The paving blocks shall preferably be those turned out by the Wisconsin Granite Co., in their quarries at Sioux Falls, S.Dak. These blocks shall have a uniform grain and texture, without lamination or stratification.

The blocks shall measure from five (5) to six (6) inches in width, from ten (10) to twelve (12) inches in length and uniformly six (6) inches in depth and to be so dressed as to have substantially rectangular, plane surfaces so that when the blocks are in place the space between the blocks shall be in no case less than one-eighth (⅛) inch nor more than three-eighths (3/8) inch. Soft or weatherworn stones, obtained from the surface of the quarry, and stones which wear to a polish under traffic, shall not be used.

The blocks shall be laid in contact with each other and in uniform courses across the roadway between the platforms. Each course shall consist of blocks of the same width and be so laid that all longitudinal joints shall be broken by a lap of at least four (4) inches.

After the blocks are in place and approved by the engineer they shall be tamped with a seventy-five (75) pound rammer to a true surface and a firm bed. No cracked or chipped blocks shall remain in the pavement.

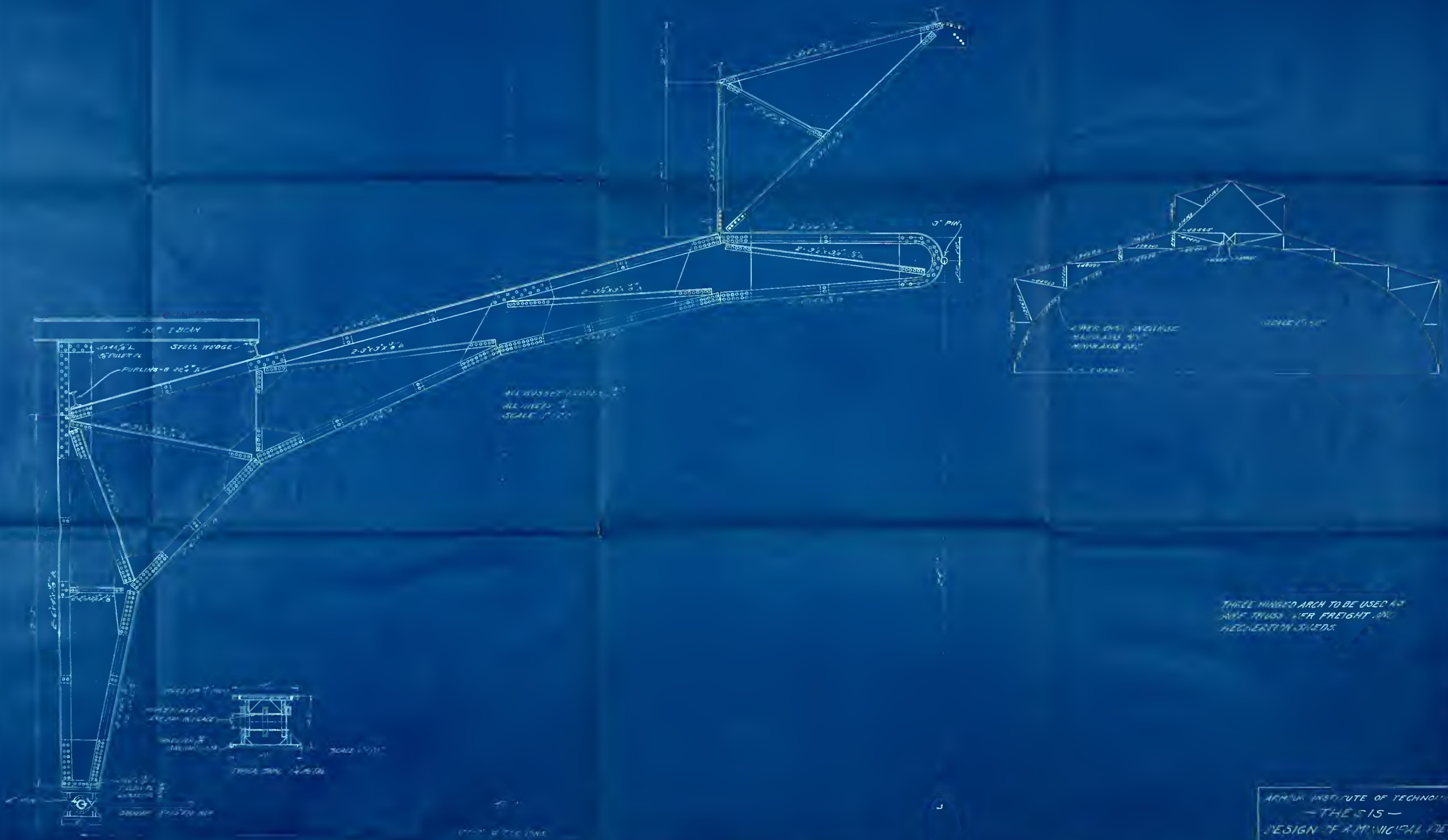
After thorough tamping the interstices shall be filled with a grout composed of one (1) part Portland Cement to one (1) part clean sharp sand. This grout is to be forced into the interstices with a squeegee or other suitable appliance approved by the engineer in charge.

At distances of every fifty feet an inch expansion joint is to be left. Same to be filled with an approved asphaltic cement.

Care must be taken that the roadways finished surface has the proper crown and pitch as sown on the plans.

ACKNOWLEDGMENTS.

The authors herein wish to extend to Mrs. Julia Beveridge, Librarian of Armour Institute of Technology, and to Prof. John C. Penn, Assistant Professor of Civil Engineering, their thanks and sincere appreciation for the valuable assistance offered in the completion of this thesis.


2" 30# I BEAM
STEEL WEDGE
PURLINS
3" PIN
ALL GUSSET PLATES
ALL RIVETS
SCALE
THREE HINGED ARCH TO BE USED AS ROOF TRUSS FOR FREIGHT AND RECREATION SHEDS.

ARMOUR INSTITUTE OF TECHNOLOGY

—THESIS—

DESIGN OF A MUNICIPAL PIER

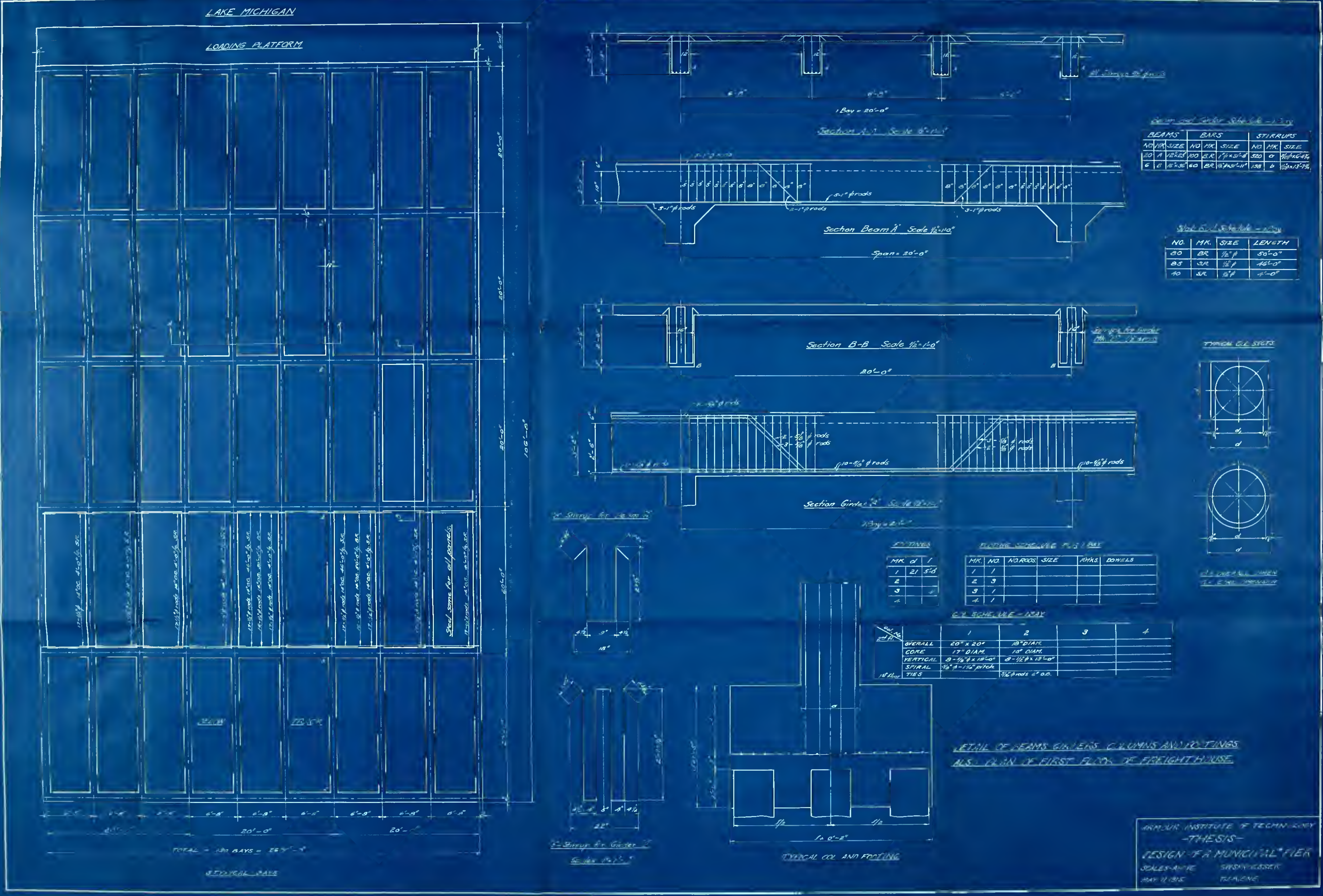
SCALE - ABOVE [illegible]

MAY 1915 [illegible]

MBR	Unity @ 2	Unity @ 3	Unity @ 4	Unity @ 1	H Unity @ 1	H Unity @ 4	DL Vert @ 2	DL Vert @ 3	DL Vert 4	Wind V. @ 2	Wind Vert @ 3	Wind Vert 4	Wind Horiz @ 1	Wind Horiz @ 4	LL Vert @ 2	LL Vert @ 1	DL Vert @ 1	WL Vert @ 1	Σ Vert DL	Actual DL Stress	Wind Σ	L.L. [illegible]	L. [illegible]	1/32 Stress
							22516#	16440#	21660#	3980#	3980#	7695#	4800#	12340#	2000#	12000#	4340#	990#						
AN'	-0.610	-1.235	-1.856	0.0	+1.915	+1.400	-13750	-20390	-45800	-2430	-4930	-14280	+9200	+17300	-7320	0.0	0.0	0.0	-79950		+4860	-1320		
AN	-0.608	-1.220	-1.794	0.0	-1.020	-1.520	+13700	-19920	-44400	-2420	-4860	-13800	-4900	-18000	-7300	0.0	0.0	0.0	-78020	-157970	-44780	-7300	-14620	-217370
AP'	-0.440	-0.883	-1.322	0.0	+1.363	+1.003	-9920	-14520	-32700	-1730	-3580	-10200	+6550	+12400	-5280	0.0	0.0	0.0	-55740		+3480	-5280		
AP	-0.433	-0.865	-1.290	0.0	-0.730	-1.085	-9760	-14220	-31850	-1725	-3440	-9940	-3500	-13400	-5200	0.0	0.0	0.0	-55830	-110970	-32005	-5200	-10480	-153455
AR'	+1.215	-0.195	-1.606	0.0	+2.075	+1.025	+27400	-3220	-39700	+4850	-780	-12350	+9980	+12700	+14600	0.0	0.0	0.0	-15520		+4400	+14600		
AR	-0.710	-1.445	-2.144	0.0	-1.220	-1.805	-16000	-23800	-53000	-2830	-5770	-16500	-5860	-22350	-8520	0.0	0.0	0.0	-92800	-118320	-53310	-8520	+6080	-180150
AT'	+1.305	+2.620	-0.722	0.0	+2.245	+2.055	+29400	+43200	-17850	+5200	+10450	-5550	+10800	+25900	+15650	0.0	0.0	0.0	+54750		+46100	+15650		
AT	-1.010	-2.070	-3.083	0.0	-1.748	-2.605	-22750	-34200	-76300	-4050	-8250	-23700	-8400	-32200	-12120	0.0	0.0	0.0	-133250	-78500	-76600	-12120	+3530	-167220
AV'	+0.418	+0.803	+1.161	0.0	+0.670	+1.025	+9430	+13200	+28750	+1670	+3200	+8950	+3220	+12900	+5040	0.0	0.0	0.0	+51380		+29740	+5040		
AV	-0.535	-1.075	-1.633	0.0	-0.920	-1.358	-12050	-17720	-40400	-2130	-4290	-12550	-4420	-16800	-6420	0.0	0.0	0.0	-70170	-18790	-40190	-6420	-1360	-65400
BN'	-0.278	+0.410	+1.122	-1.000	-1.590	-1.008	-6730	+6750	+27700	-1190	+1630	+8650	-7650	-12450	-3580	-12000	-14300	-1990	+11430		-13600	-15580		
MN	+0.450	+0.898	+1.30	0.0	+0.745	+1.115	+10140	+14790	+32200	+1790	+3580	+10000	+3580	+13800	+5400	0.0	0.0	0.0	+57130	+168360	+32750	+5400	-10180	+106710
BO'	-0.298	+0.410	+1.122	-1.000	-1.590	-1.008	-6730	+6750	+27700	-1190	+1630	+8650	-7650	-12950	-3580	-12000	-14300	-1990	+11430		-13000	-15580		
MO	+0.450	+0.898	+1.300	0.0	+0.745	+1.115	+10140	+14790	+32200	+1790	+3580	+10000	+3580	+13800	+5400	0.0	0.0	0.0	+57130	+168560	+32750	+5400	-10180	+106710
CO'	-1.355	-0.248	+0.856	0.0	-2.308	-1.035	-30600	-4080	+21150	-5400	-990	+6600	-11100	-12800	-16250	0.0	0.0	0.0	-13530		-23690	-16250		
LO	+0.448	+0.915	+1.344	0.0	+0.773	+1.140	+10100	+1510	+33200	+1780	+3640	+10340	+3710	+14100	+5380	0.0	0.0	0.0	+44810	+31280	+33570	+5380	-10870	+70230
DS'	-1.535	-3.098	+4.080	0.0	-2.64	-1.58	-34630	-50600	+1975	-6120	-12500	+615	-12700	-29550	-18450	0.0	0.0	0.0	-83255		-50255	-18450		
KS	+0.805	+1.670	+2.472	0.0	+1.410	+2.098	+18150	+27500	+61000	+3210	+6660	+19000	+6760	+26000	+9660	0.0	0.0	0.0	+106650	+23395	+61630	+9660	-8790	+94685
EU'	-0.647	-1.260	-1.844	0.0	-1.055	-0.565	-14600	-20750	-45600	-2580	-5050	-14200	-5060	-7000	-7770	0.0	0.0	0.0	-80950		-33890	-7770		
JU	+0.330	+0.678	+1.036	0.0	+0.585	+0.858	+7620	+11150	+25600	+1350	+2780	+7960	+2810	+10600	+4060	0.0	0.0	0.0	+44370	-36580	+25500	+4060	-3710	-78240
XW'	-0.165	-0.335	-0.500	0.0	-0.275	-0.418	-3720	-5520	-12330	-660	-1340	-3850	-1320	-5180	-1980	0.0	0.0	0.0	-21570		-12350	-1980		
XW	-0.043	-0.083	-0.128	0.0	-0.070	-0.105	-970	-1365	-3810	-172	-330	-985	-340	-1300	-520	0.0	0.0	0.0	-6145	-27715	-3127	-520	-2560	-42565
O'N'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q'P'	+1.430	+0.460	-0.505	0.0	+0.910	+0.765	+32200	+7570	-12500	+5700	+1830	-3880	+4370	+9460	+17200	0.0	0.0	0.0	+27270		+17480	+17200		
QP	-0.330	-0.680	-1.000	0.0	-0.573	-0.850	-7440	-11200	-24660	-1315	-2710	-7695	-2750	-10500	-3960	0.0	0.0	0.0	-43300	-16030	-24970	-3960	+13240	-44960
Q'R'	-1.043	-0.600	-0.162	0.0	-0.070	-0.115	-23500	-9890	-4000	-4160	-2390	-1250	-340	-1420	-12530	0.0	0.0	0.0	-37390		-9560	-12530		
QR	+0.075	+0.150	+0.288	0.0	+0.130	+0.190	+1690	+2470	+7120	+300	+600	+2220	+625	+2350	+900	0.0	0.0	0.0	+11280	-26110	+6095	+900	-11630	-48200
R'S'	+0.175	+2.735	+0.750	0.0	+0.320	+0.528	+3940	+45000	+18550	+700	+10900	+5770	+1540	+6540	+2100	0.0	0.0	0.0	+67490		+25450	+2100		
RS	-0.348	-0.730	-1.090	0.0	-0.618	-0.928	-7850	-12100	-27000	-1390	-2910	-8400	-2970	-11470	-4180	0.0	0.0	0.0	-46950	+20540	-27140	-4180	-2080	+48090
S'T'	+0.233	-0.523	-0.483	0.0	+0.20	+0.263	+5250	-8600	-11920	+930	-2080	-3720	+960	+3250	+2880	0.0	0.0	0.0	-15270		-660	+2600		
ST	-0.123	-0.255	-0.370	0.0	-0.215	-0.315	-2770	-4200	-9150	-490	-1020	-2840	-1030	-3900	-1480	0.0	0.0	0.0	-16120	-31390	-9280	-1480	+1320	-42150
T'U'	-0.856	-1.753	+1.858	0.0	-0.530	-0.980	-19300	-28900	+45900	-3420	-7000	+14300	-2540	-12100	-10360	0.0	0.0	0.0	-2300		-10760	-10300		
TU	+0.453	+0.958	+1.390	0.0	+0.793	+1.195	+10200	+15780	+34400	+1810	+3820	+10700	+3800	+14800	+5430	0.0	0.0	0.0	+60380	+58080	+34930	+5430	-4870	+98340
U'V'	+0.258	+0.507	-0.250	0.0	+0.430	+0.375	+5810	+8350	-6180	+1030	+2020	-1920	+2060	+4640	+3100	0.0	0.0	0.0	+7980		+7830	+3100		
UV	-0.160	-0.325	-0.500	0.0	-0.277	-0.413	-3610	-5350	-12390	-640	-1300	-3850	-1330	-5100	-1920	0.0	0.0	0.0	-21290	-13310	-12220	-1420	+1180	-27450
V'W'	-0.465	-0.960	-1.311	0.0	-0.758	-1.145	-10490	-14800	-32400	-1850	-3590	-10100	-3640	-14200	-5590	0.0	0.0	0.0	-57690		-33440	-5590		
VW	+0.375	+0.753	+1.150	0.0	+0.650	+0.953	+8450	+12400	+28400	+1495	+3000	+8850	+3120	+11700	+4500	0.0	0.0	0.0	+49250	-8440	+28245	+4500	-1090	-47470
W1	+0.165	+0.325	+0.500	0.0	+0.275	+0.418	+3720	+5350	+12330	+660	+1290	+3850	+1320	+5180	+1980	0.0	0.0	0.0	+21400		+12300	+1980		
W2	+0.043	+0.083	+0.128	0.0	+0.070	+0.105	+970	+1365	+3160	+172	-330	-985	+340	+1300	+520	0.0	0.0	0.0	+5495	+26895	+497	+520	+2500	+41695
O'P'	-0.293	-0.588	-0.886	0.0	+0.918	+0.665	-6600	-9680	-21900	-1690	-2340	-6820	+4400	+8230	-3520	0.0	0.0	0.0	-38180		+1780	-3520		
OP	-0.295	-0.590	-0.853	0.0	-0.485	-0.725	-6650	-9760	-21100	-1750	-2350	-6560	-2330	-8980	-3540	0.0	0.0	0.0	-37460	-75640	-21970	-3540	-7060	-104670
A1	-0.055	-0.118	-0.179	0.0	-0.10	-0.147	-1240	-1940	-4430	-220	-470	-1380	-480	-1820	-660	0.0	0.0	0.0	-7610		-4370	-660		
A2	-0.230	-0.470	-0.706	0.0	-0.395	-0.588	-5190	-7740	-17450	-920	-1880	-5440	-1900	-7270	-2760	0.0	0.0	0.0	-30380	-37990	-17410	-2760	-3420	-58820
X1	-0.230	-0.470	-0.706	0.0	-0.395	-0.588	-5190	-7740	-17450	-920	-1880	-5440	-1900	-7270	-2760	0.0	0.0	0.0	-30380		-17410	-2760		
X2	-0.055	-0.118	-0.179	0.0	-0.10	-0.147	-1240	-1940	-4430	-220	-470	-1380	-480	-1820	-660	0.0	0.0	0.0	-7610	-37990	-4370	-660	-3420	-58820

CALCULATION OF STRESSES FOR THE
DESIGN OF MEMBERS IN THE THREE
HINGED ROOF ARCH

ARMOUR INSTITUTE OF TECHNOLOGY
— THESIS —
DESIGN OF A MUNICIPAL PIER
[illegible] GW STRUESSER
MAY 1915 TJ KNE



Beam and Girder Schedule - 1 Bay

BEAMS			BARS			STIRRUPS		
NO.	MK.	SIZE	NO.	MK.	SIZE	NO.	MK.	SIZE
20	A	12"×25"	100	B.R.	1"φ×31'-8"	520	a	3/8"φ×6'-4 3/4
6	B	16"×36"	60	BR.	1/2"φ×31'-11"	138	b	1/2"φ×13'-7 3/4

Slab Steel Schedule - 1 Bay

NO.	MK.	SIZE	LENGTH
80	BR.	1/2" φ	50'-0"
85	SR.	1/2" φ	46'-0"
40	SR.	1/2" φ	4'-0"

FOOTINGS

MK.	d	l
1	21	5'-6
2		
3		
4		

FOOTING SCHEDULE FOR 1 BAY

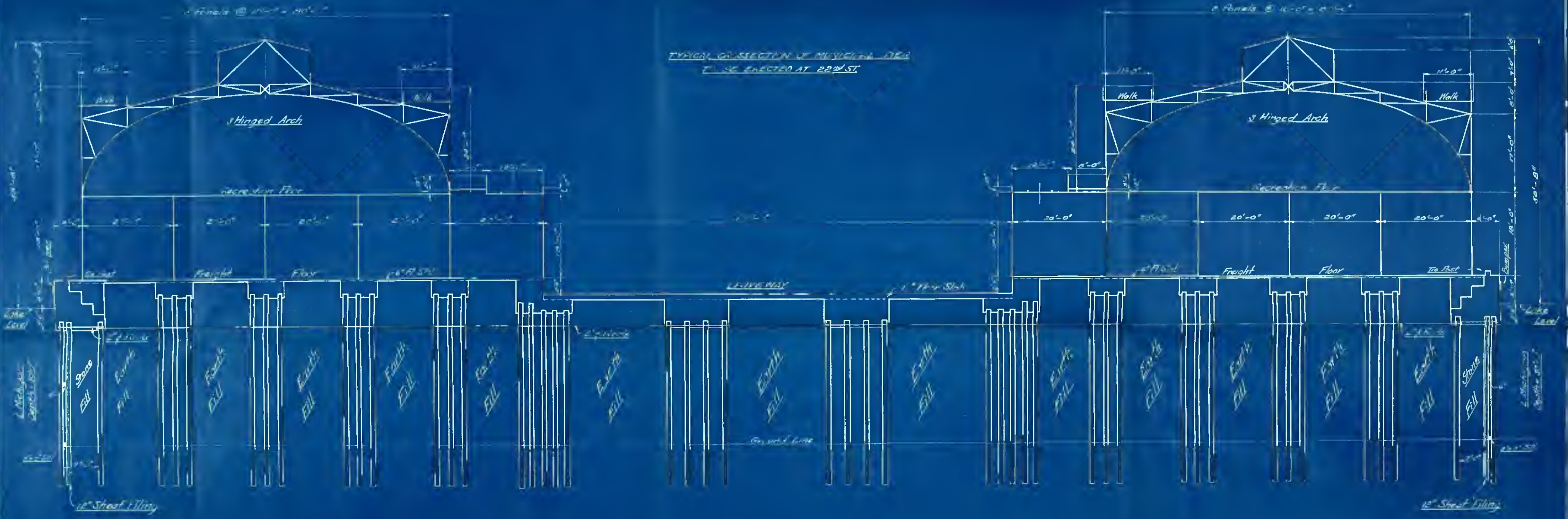
MK.	NO.	NO. RODS.	SIZE	RMKS.	DOWELS
1	1				
2	3				
3	1				
4	1				

COL. SCHEDULE - 1 BAY

Col. No. / 2nd Fl.		1	2	3	4
	OVERALL	20" x 20"	18" DIAM.		
	CORE	17" DIAM.	16" DIAM.		
	VERTICAL	8-5/8"φ x 19'-0"	8-1/2"φ x 13'-0"		
	SPIRAL	3/8" φ-1 1/4" pitch			
1st floor	TIES		3/16"φ rods 6" O.C.		

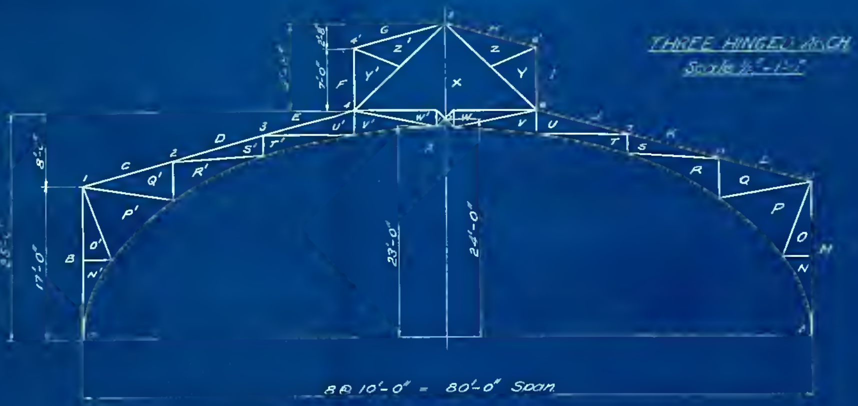
DETAIL OF BEAMS GIRDERS COLUMNS AND FOOTINGS
ALSO PLAN OF FIRST FLOOR OF FREIGHT HOUSE

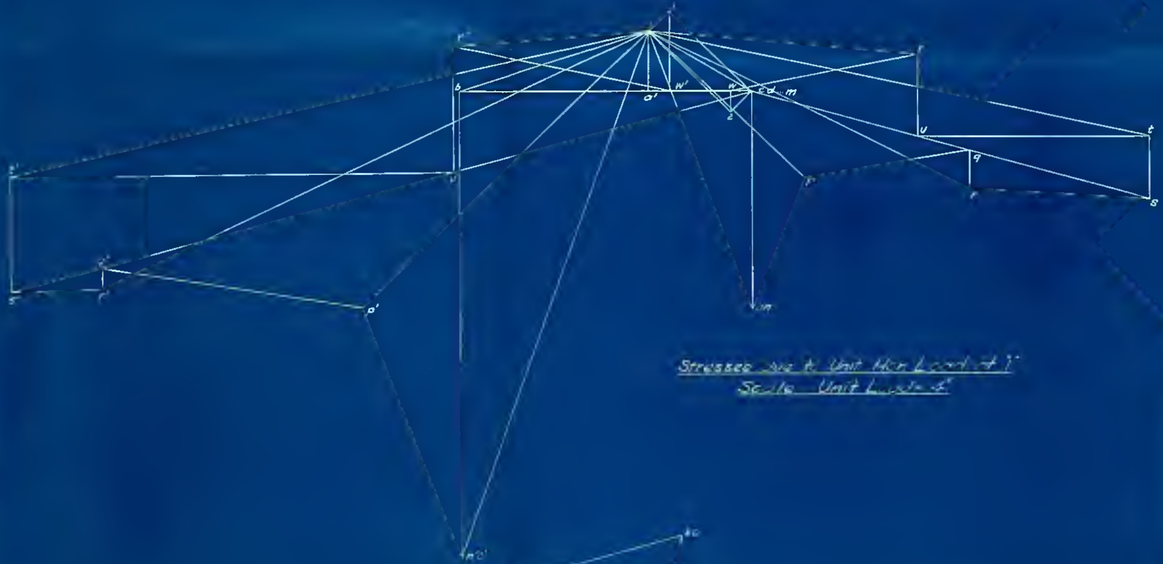
ARMOUR INSTITUTE OF TECHNOLOGY
-THESIS-
DESIGN OF A MUNICIPAL PIER
SCALES-ABOVE
MAY 11 1915



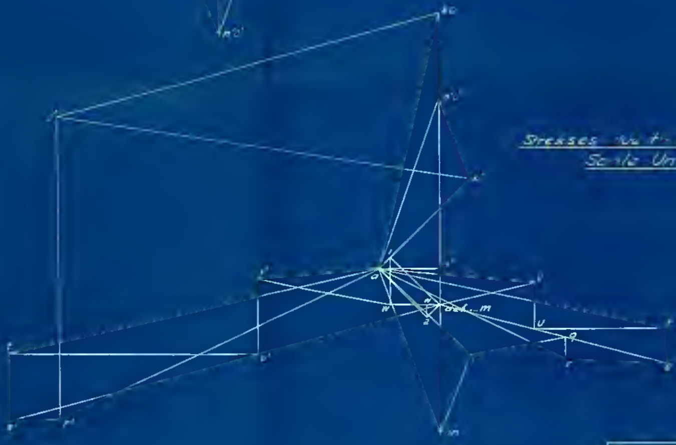
ARMOUR INSTITUTE OF TECHNOLOGY
-THESIS-
DESIGN OF A MUNICIPAL PIER
SCALE-1/8"=1FT
MAY 12 1915
G.W.SCHROESSER.
T.J.KIENE.

THREE HINGED ARCH
Scale 1/8" = 1'-0"





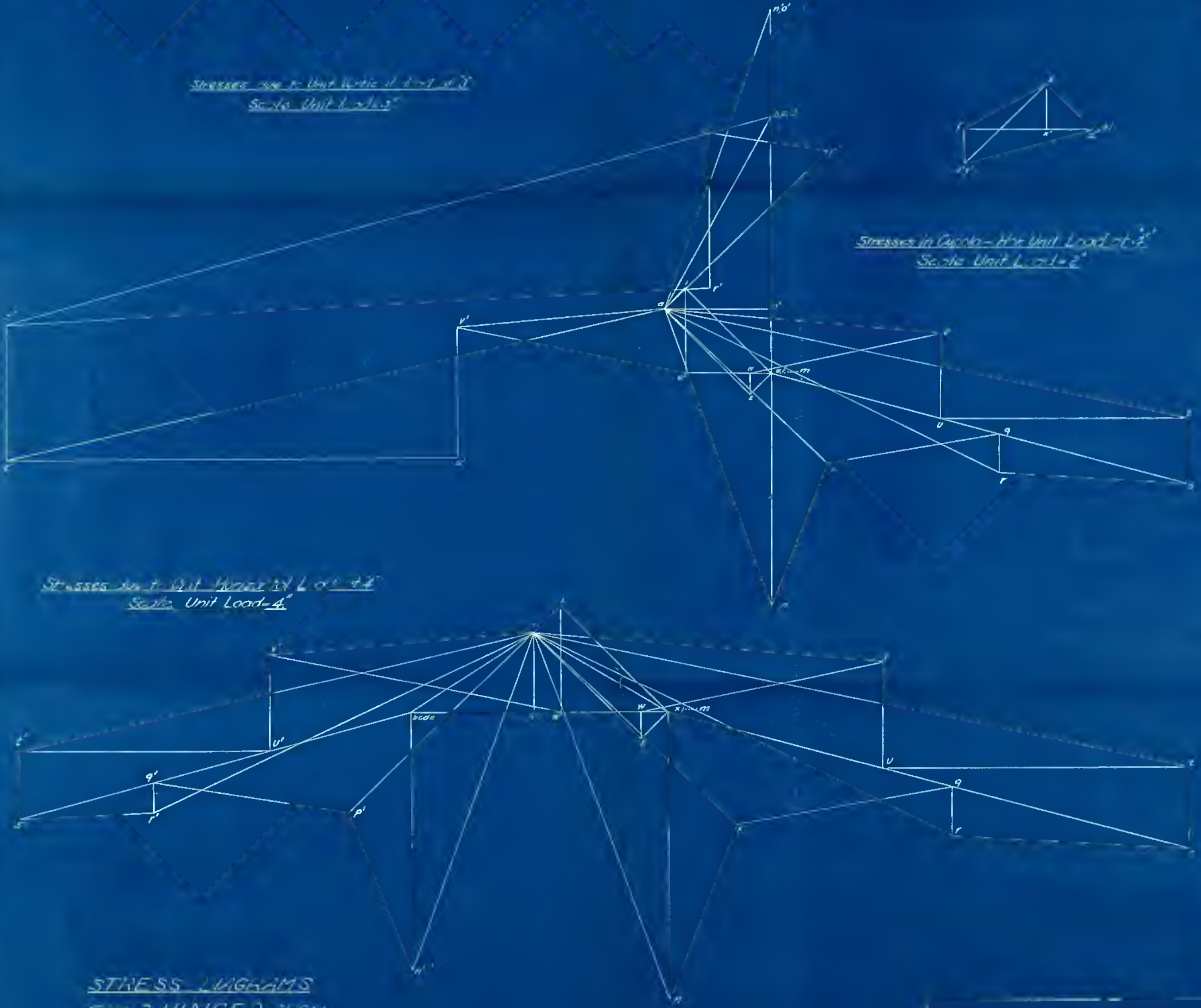
Stresses due to Unit Hor Load at 1'
Scale Unit Load = 4"



Stresses due to Unit Vert Load at 2'
Scale Unit Load = 4"

STRESS DIAGRAMS
FOR THREE HINGED ARCH

ARMOUR INSTITUTE OF TECHNOLOGY
—THESIS—
DESIGN OF A MUNICIPAL PIER
SCALE ABOVE G.W. SPIX ESSEX.
APR. 12 1915 T.J. KIENE.



Stresses due to Unit Vertical Load at 3'
Scale Unit Load = 3"

Stresses in Cupola – Hor. Unit Load at 2'
Scale Unit Load = 2"

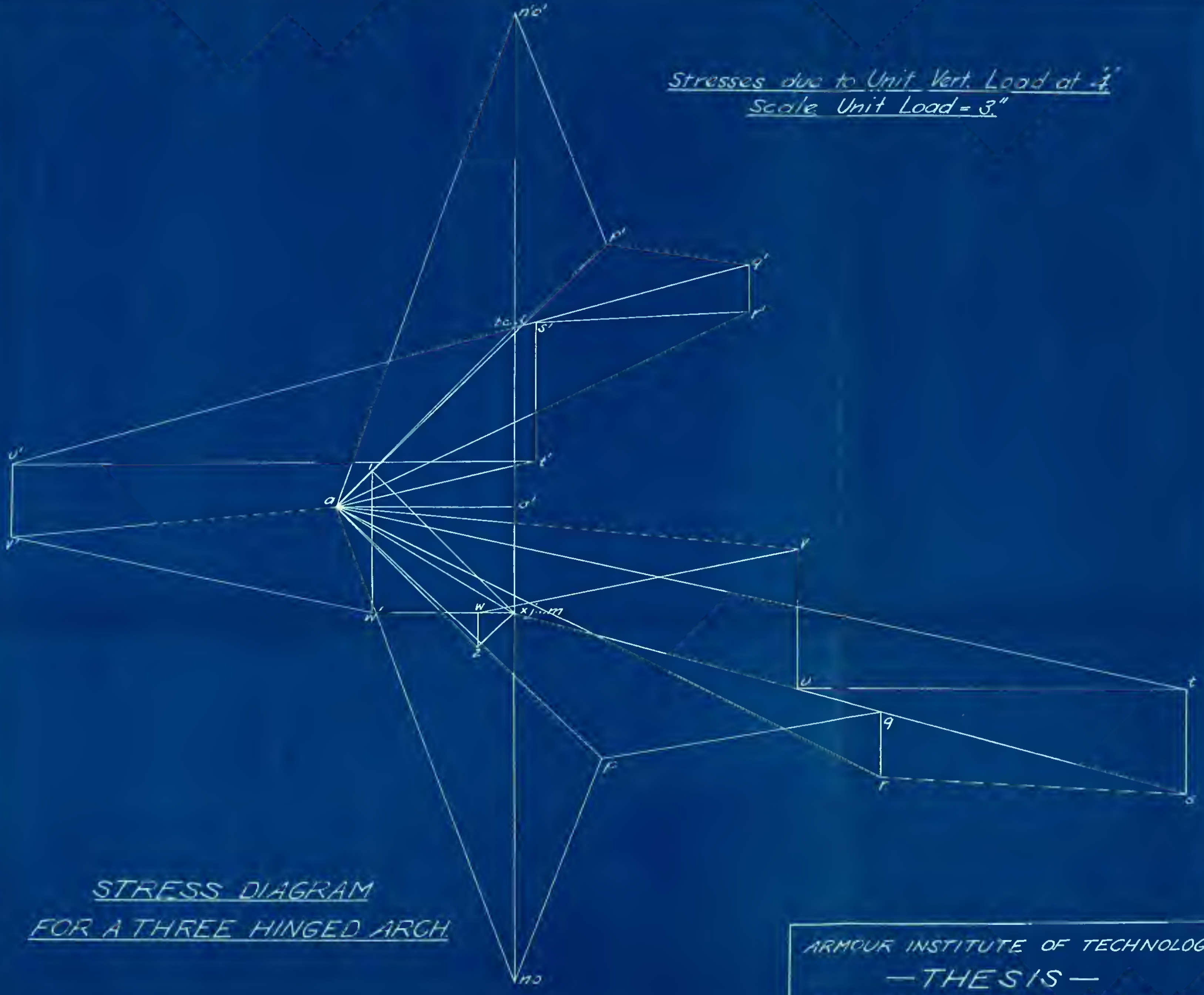
Stresses due to Unit Horizontal Load at 4'
Scale Unit Load = 4"

STRESS DIAGRAMS
FOR 3 HINGED ARCH

ARMOUR INSTITUTE OF TECHNOLOGY
— THESIS —
DESIGN OF A MUNICIPAL PIER
SCALE – ABOVE G.W. SPROESSER.
APR. 19, 1915 T.J. KIENE.

Stresses due to Unit Vert. Load at "I"

Scale Unit Load = 3"



STRESS DIAGRAM FOR A THREE HINGED ARCH

ARMOUR INSTITUTE OF TECHNOLOGY

— THESIS —

DESIGN OF A MUNICIPAL PIER

SCALE - ABOVE G.W. STROESSER.

APR. 19, 1915. T.J. KIENE.

INSERT
FOLD-OUT
OR MAP
HERE!